US009458844B2

(12) **United States Patent**
Gieras et al.

(10) **Patent No.: US 9,458,844 B2**
(45) **Date of Patent: Oct. 4, 2016**

(54) **PROPELLER ROTOR AND ENGINE OVERSPEED CONTROL**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 704 days.

(21) Appl. No.: **13/924,050**

(22) Filed: **Jun. 21, 2013**

(65) **Prior Publication Data**

US 2014/0377079 A1 Dec. 25, 2014

(51) **Int. Cl.**

F04B 35/04	(2006.01)
B64D 35/00	(2006.01)
H02K 49/04	(2006.01)
B60T 13/74	(2006.01)
F16D 63/00	(2006.01)

(52) **U.S. Cl.**

CPC ***F04B 35/04*** (2013.01); ***B60T 13/748*** (2013.01); ***B64D 35/00*** (2013.01); ***F16D 63/002*** (2013.01); ***H02K 49/043*** (2013.01)

(58) **Field of Classification Search**

CPC B64C 11/00; B64C 13/00; B64C 13/24; B64C 2013/00; B64C 2013/24; F16D 13/30; F16D 13/24; F16D 13/26; F16D 13/28; F16D 7/028

See application file for complete search history.

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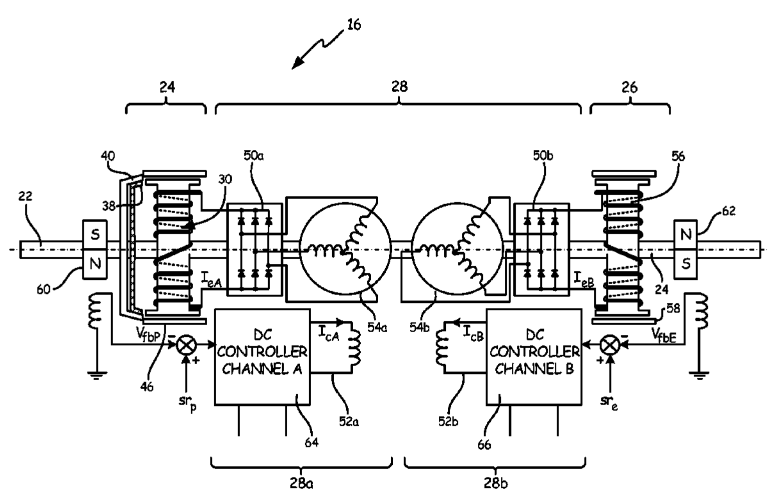
(57) **ABSTRACT**

An electromagnetic device for overspeed control of a propeller driven by an engine shaft comprises a clutch, an eddy-current coupler, and an electromagnetic brake. The clutch is disposed to mechanically decouple the propeller from the engine shaft. The eddy current coupler is disposed to electromagnetically couple the propeller to the engine shaft when the clutch mechanically decouples the propeller from the engine shaft. The electronic brake is disposed to artificially load the engine shaft when the propeller load on the engine shaft is reduced by mechanically decoupling the propeller from the engine shaft.

17 Claims, 3 Drawing Sheets



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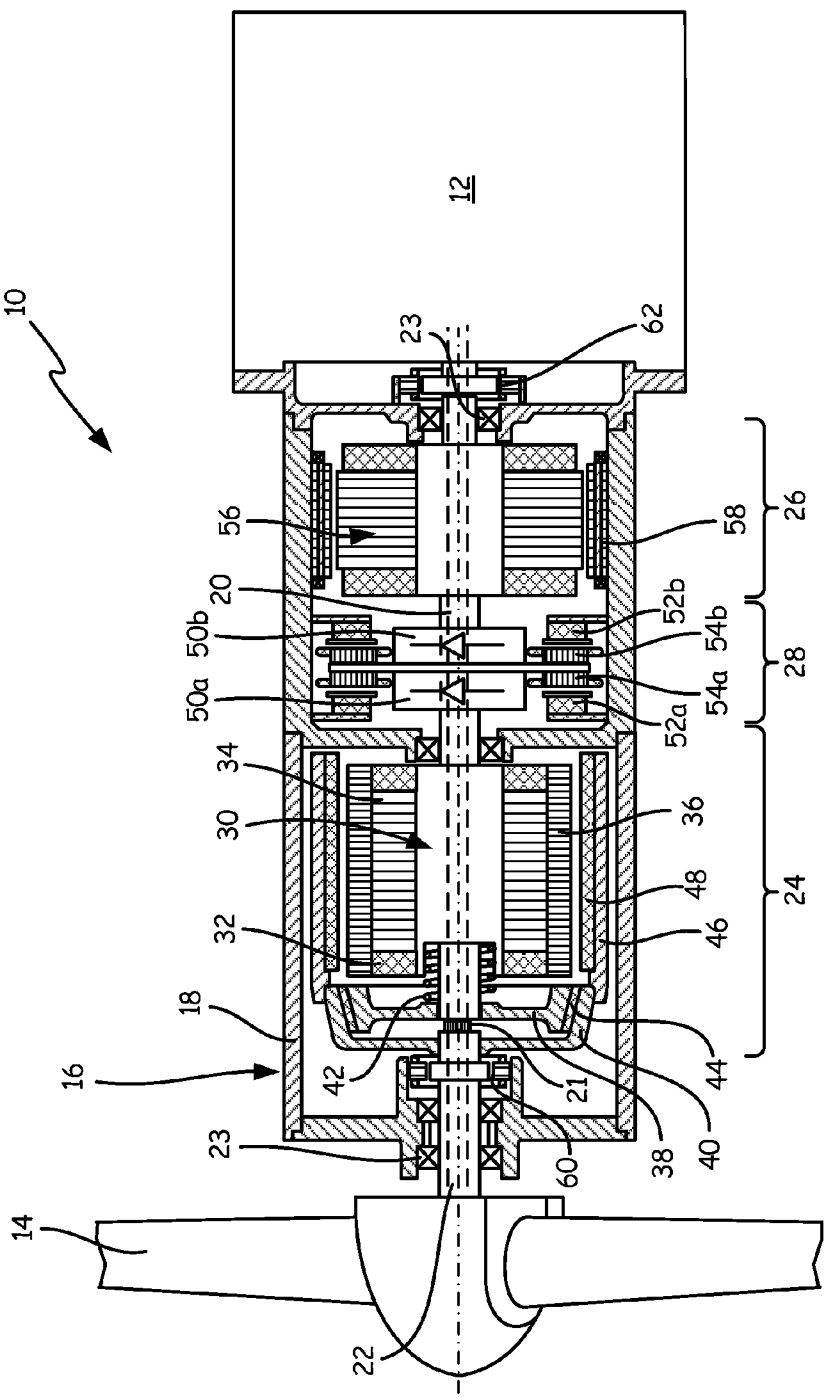
10
12
23
62
56
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26
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50b
52b
54b
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50a
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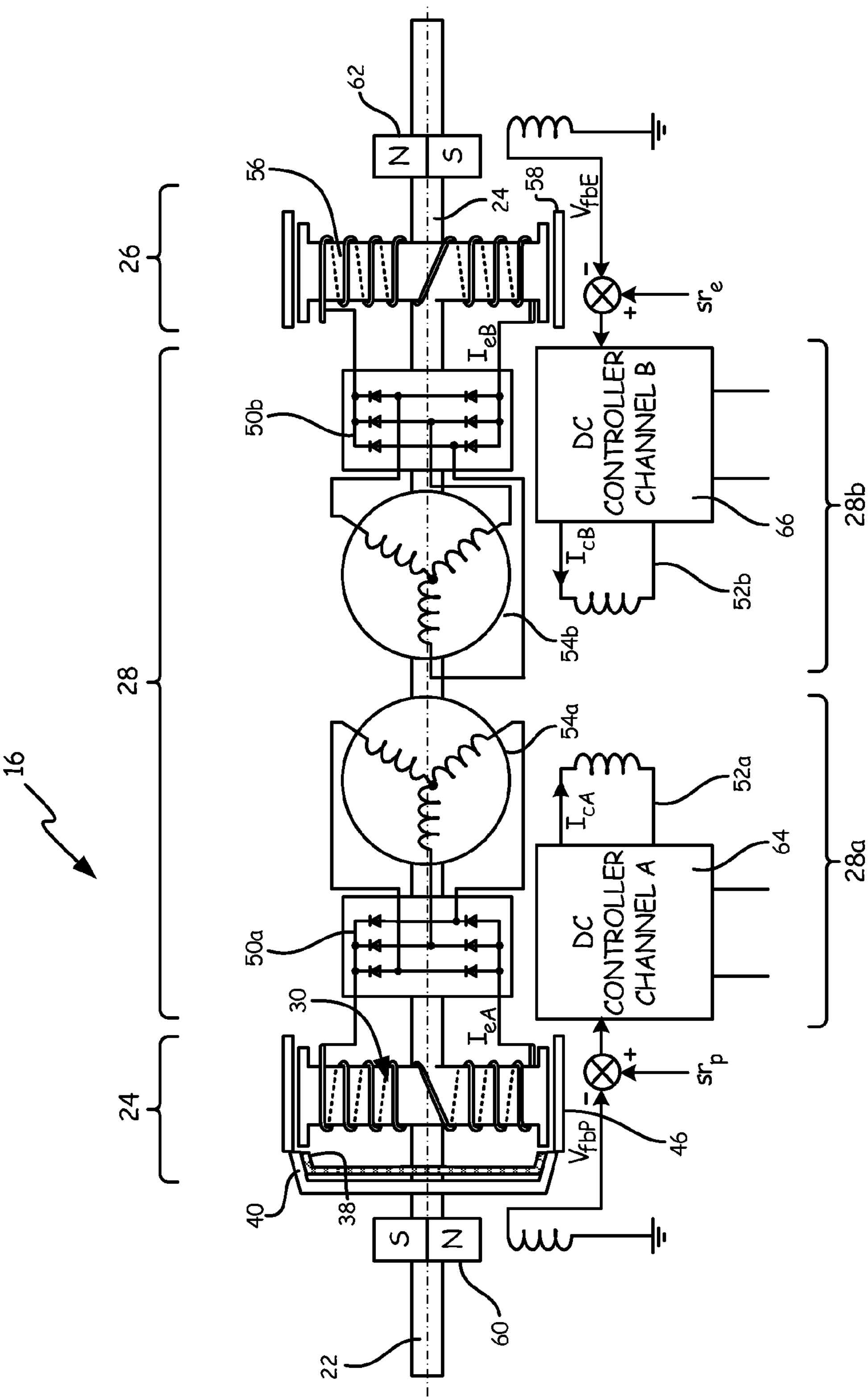
FIG. 1



16
24
26
28
28a
28b
DC CONTROLLER CHANNEL A
DC CONTROLLER CHANNEL B
N
S
sr_p
sr_e
V_fbP
V_fbE
I_eA
I_eB
I_cA
I_cB

FIG. 2

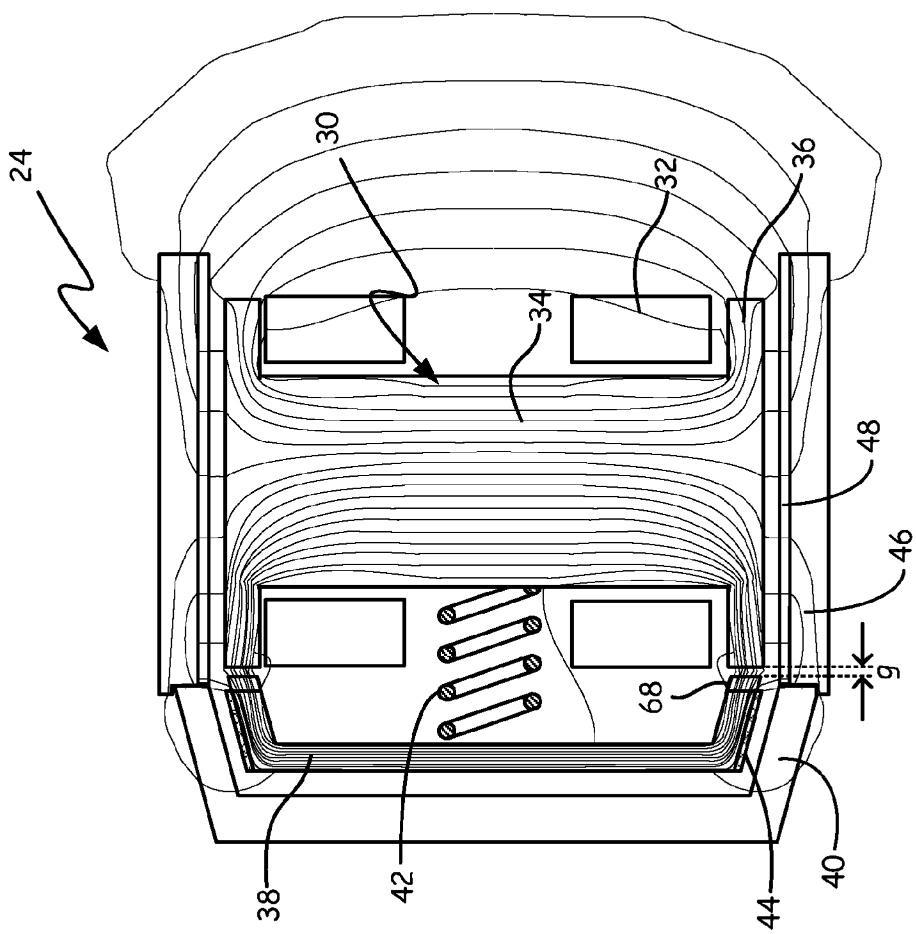


FIG. 3

PROPELLER ROTOR AND ENGINE OVERSPEED CONTROL

BACKGROUND

The present invention relates generally to torque coupling devices, and more particularly to an electromechanical coupling assembly for avoidance and control of rotor overspeed conditions during propeller pitch control operation.

Engine overspeed is a major concern for turboprop engines, particularly during landing maneuvers. During landing, turboprop vehicles often control blade pitch to reverse the angle of attack of propeller blades. If blade pitch reversal is too gradual, propeller blades may be driven by airflow, rather than the reverse, transmitting harmful torque to the turboprop engine. This can erode the propeller blades, and can cause catastrophic damage to the turboprop engine. Most turboprop vehicles reverse blade pitch very quickly to avoid these conditions. Rapid propeller blade pitching poses its own challenges, however, as blades may be briefly unloaded when pitched edgewise into the wind while transitioning to a reverse pitch. This transient unloading of the propeller blades can cause harmful engine rotor overspeeds.

To avoid engine damage from engine shaft overspeeds, many turboprop systems spool engines down during propeller blade pitch reversal and rely on engine overspeed limiters that close fuel supply governor valves and shut down or reduce fuel to engine(s) if engine overspeed conditions are detected. Once spooled down, an engine requires significant time to spool back up. Consequently, the engine may be incapable of producing the required torque and propeller thrust to respond to an aborted landing command in time to regain altitude and avoid ground obstacles.

SUMMARY

The present invention is directed toward an electromagnetic device for overspeed control of an engine whose output shaft drives a propeller. The electromagnetic device comprises a clutch, an eddy-current coupler, and an electromagnetic brake. The clutch is disposed to mechanically decouple the propeller from the engine shaft. The eddy current coupler is disposed to electromagnetically couple the propeller to the engine shaft when the clutch mechanically decouples the propeller from the engine shaft. The electromagnetic brake is disposed to artificially load the engine shaft when the propeller load on the engine shaft is reduced by mechanically decoupling the propeller from the engine shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified cross-sectional view of a propeller system that utilizes an electromagnetic (EM) device for overspeed control.

FIG. **2** is a schematic view of the EM device of FIG. **1**.

FIG. **3** is a close-up of the simplified cross-sectional view of FIG. **1**, illustrating the operation of an electromechanical (ELM) clutch and eddy-current coupler.

DETAILED DESCRIPTION

FIG. **1** is a simplified cross-sectional view of propeller system **10**, comprising engine **12**, propeller **14**, and electromagnetic (EM) device **16**. EM device **16** is a torque transfer apparatus that transmits torque from engine **12** to propeller **14**. EM device **16** comprises housing **18**, engine shaft **20**, pitch control shaft **21**, propeller shaft **22**, bearings **23**,

electromechanical (ELM) clutch and eddy-current coupler **24**, electromagnetic (EM) brake **26**, and double-channel exciter **28**. ELM clutch and eddy-current coupler **24** is a hybrid clutch machine comprising field exciter **30**, field coils **32**, pole cores **34**, pole shoes **36**, friction clutch cone **38**, friction clutch cup **40**, spring **42**, clutch pad **44**, rotating drum **46**, and electric circuit **48**. Double-channel exciter **28** is a dual-feed rotary electromagnetic exciter that feeds both integrated ELM clutch and eddy current coupler **24** and electromagnetic brake **26**, and that comprises rotating rectifiers **50***a* and **50***b*, excitation windings **52***a* and **52***b*, and rotating armatures **54***a* and **54***b*. EM brake **26** is an artificial loading mechanism comprising rotating field exciter **56** and external electric circuit **58**. EM device **16** further comprises permanent magnet (PM) tachogenerators **60** and **62**, which produce feedback voltages V_{fbP} and V_{fbE} proportional to the speeds of propeller shaft **22** and engine shaft **20**, respectively.

EM device **16** is a torque transfer system disposed to carry torque from engine **12** to propeller **14**. Engine **12** may be any appropriate rotary engine, such as a gas turbine engine. Propeller **14** is a rotating assembly comprising a plurality of pitch-controlled blades extending substantially radially outward from a common hub. Propeller **14** may, for instance, be a propeller for propulsion of a turboprop aircraft. Engine **12** drives propeller **14** via EM device **16**, which can mechanically decouple and electromagnetically couple engine shaft **20** and propeller shaft **22** as needed to avoid overspeed conditions, while artificially loading engine shaft **20** to compensate for decreases in load lost by decoupling engine shaft **20** from propeller shaft **22**. Engine **12** drives engine shaft **20**, while propeller shaft **22** drives propeller **14**. In the illustrated embodiment, propeller shaft **22** and engine shaft **20** are hollows shafts concentrically disposed about pitch control shaft **21**, a control shaft disposed to control the pitch of blade of propeller **14**. In the illustrated embodiment, pitch control shaft **21** slides axially inside the engine shaft **20** and propeller shaft **22** to alter the pitch of blades of propeller **14**. Engine **12** need not drive engine shaft **20** directly; many embodiments of propeller system **10** may utilize gearboxes or step-down gears to transfer torque from engine **12** to engine shaft **20**.

EM device **16** is contained within housing **18**, a rigid supportive and protective case that carries ELM clutch and eddy current coupler **24**, EM brake **26**, and double-channel exciter **28**. Bearings **23** are disposed on housing **18** to rotatably support propeller shaft **22** and engine shaft **20**. Bearings **23** may, for instance, be roller or ball bearings.

ELM clutch and eddy-current coupler **24** provides scalable torque coupling between propeller shaft **22** and engine shaft **20**. Field exciter **30** of ELM clutch and eddy-current coupler **24** is a rotating cylindrical device with field coils **32**, pole cores **34**, and pole shoe **36**. Field exciter **30** rotates on engine shaft **20**. Field coils **32** are windings wrapped about pole cores **34** so as to produce a magnetic field near pole shoe **36** when energized by double-channel exciter **28**. Pole cores **34** are radially-aligned supports distributed at circumferential intervals about field exciter **30**, and may for instance be formed of steel or another ferromagnetic material. Some embodiments of field exciter **30** may, for example, have six substantially symmetrically distributed pole cores **34**. Pole shoes **36** are ferromagnetic blocks disposed at the outer radial extents of pole cores **34** to face rotating drum **46** and electric circuit **48** (described below).

Engine shaft **20** terminates in friction clutch cone **38**, and propeller shaft **22** terminates in friction clutch cup **40** of ELM clutch and eddy-current coupler **24**. Friction clutch cone **38** is formed of steel or another rigid ferromagnetic material, while friction clutch cup **40** may be formed of any rigid material with appropriate torsional strength. Spring **42** biases friction clutch cone **38** to contact clutch pad **44**, a friction pad disposed on an inner surface of friction clutch cup **40** facing friction clutch cone **38**. In some embodiments, spring **42** may be replaced by a short-stroke linear electromagnetic actuator, or analogous device. So long as friction clutch cone **38** remains in contact with clutch pad **44** on friction clutch cup **40**, propeller shaft **22** and engine shaft **20** remain rigidly mechanically coupled. This is the ordinary operation mode of ELM clutch and eddy-current coupler **24**, connecting propeller shaft **22** to engine shaft **20** to transfer torque substantially losslessly from engine **12** to propeller **14**. Rotating drum **46** is a cylindrical structure anchored to friction clutch cup **40** that surrounds field exciter **30**. Rotating drum **46** supports electric circuit **48** (e.g. a cage winding, copper layer, or similar conductive structure), which opposes pole shoes **36** across a narrow air gap.

Field coils **32** of field exciter **30** can be energized to mechanically decouple friction clutch cone **38** from friction clutch cup **40**, and electromagnetically couple field exciter **30** to rotating drum **46**. When field coils **32** are energized by double-channel exciter **28**, rotation of field exciter **30** induces eddy currents in electric circuit **48** proportional to the strength of the coupler energizing current I_{eA} (see FIG. **2**, described below). Magnetic attraction forces between friction clutch cone **38** and pole shoe **36** draw friction clutch cone **38** and attached clutch pad **44** away from friction clutch cup **40**, thus severing the mechanical coupling between friction clutch cone **38** and friction clutch cup **40**, and thereby between engine shaft **20** and propeller shaft **22**. Eddy current coupling between pole shoes **36** and electric circuit **48** simultaneously carries torque from field exciter **30** to rotating drum **46**, and thereby to propeller shaft **22**, causing rotating drum **46**, friction clutch cup **40**, and propeller shaft **22** to rotate in the direction of engine shaft **20** despite the mechanical decoupling. The strength of electromagnetic torque coupling between rotating drum **46** and pole shoes **36** depends on the strength of the induced eddy currents, and therefore on the strength of coupler energizing current I_{eA}. In general, the rotational speed ν_p of propeller shaft **22** is related to the rotational speed ν_e of engine shaft **20** by slip s, such that:

$$\nu_p=(1-s)\nu_e \qquad \text{[Equation 1]}$$

where s is substantially zero while friction clutch cone **38** is mechanically coupled to friction clutch cup **40**, and where s decreases as I_{eA} increases during electromagnetic coupling of field exciter **30** to rotating drum **46**. Thus, the torque coupling between propeller shaft **22** and engine shaft **20** can be adjusted by varying I_{eA}.

EM brake **26** operates on similar principles to ELM clutch and eddy-current coupler **24**. EM brake **26** comprises rotating field exciter **56**, a substantially cylindrical structure with a plurality of coils wound on ferromagnetic cores supported on engine shaft **20**. Rotating field exciter **56** is surrounded by external electric circuit **58** (e.g. a cage winding, copper layer, or similar structure), which is supported on housing **18**. Rotation of rotating field exciter **56** induces eddy currents in external electric circuit **58** when rotating field exciter **56** is energized by brake energizing current I_{eB} from double-channel exciter **28**, much as discussed above with respect to field exciter **30** in the context of ELM clutch and eddy-current coupler **24**. These eddy currents cause torque coupling between rotating field exciter **56** and external electric circuit **58**, which is anchored to housing **18**. Since housing **18** is a stationary structure, this torque coupling causes external electric circuit **58** to exert a braking torque on rotating field exciter **56** proportional to brake energizing current I_{eB}.

While engine shaft **20** is mechanically decoupled from propeller shaft **22** by ELM clutch and eddy-current coupler **24**, increased speed ν_p results in decreasing load on drive shaft **20**. To avoid engine overspeeds, electromagnetic brake **26** artificially loads engine shaft **20**, thereby allowing engine **12** to operate at full power during pitch reversal (e.g. for landing maneuvers) of propeller **14** without risk of damaging overspeeds to engine **12**.

Double-channel exciter **28** is a wound-field synchronous generator driven by engine shaft **20** that delivers coupler and brake energizing currents I_{eA} and I_{eB} to field exciter **30** and rotating field exciter **56**, respectively. Double-channel exciter **28** comprises first and second rotating rectifiers **50*a*** and **50*b***, first and second excitation windings **52*a*** and **52*b***, and first and second rotating armatures **54*a*** and **54*b***, respectively. Rotating rectifiers **50*a*** and **50*b*** are conventional rotating rectifiers. Excitation windings **52*a*** and **52*b*** are stationary windings anchored to casing **18** that are energized separately by DC control currents. Rotating armatures **54*a*** and **54*b*** are rotating structures comprising a plurality of wound ferromagnetic cores supported on engine shaft **20**. AC voltage produced by the movement of windings on rotating armatures **54*a*** and **54*b*** are rectified by rotating rectifier **50*a*** and **50*b***, respectively, and fed to ELM clutch and eddy-current coupler **24** and EM brake **26**, respectively.

Tachogenerators **60** and **62** are permanent magnet or other generators disposed on propeller shaft **22** and engine shaft **20**, respectively. Tachogenerators **60** and **62** generate small amplitude feedback signals proportional to the speed of propeller shaft **22** and engine shaft **20**, respectively, that are used to produce the DC control currents of excitation windings **52*a*** and **52*b***, as described below with respect to FIG. **2**.

FIG. **2** is a schematic view of EM device **16** in isolation. FIGS. **1** and **2** depict the same embodiment of EM device **16**, and illustrate substantially the same elements as described above. As discussed with respect to FIG. **1**, field coils **32** of field exciter **30** of integrated ELM clutch and eddy-current coupler **24** can be energized via coupler energizing current I_{eA} from double-channel synchronous exciter **28** to mechanically decouple propeller shaft **22** from engine shaft **20** by magnetically pulling friction clutch cone **38** away from friction clutch cup **40**. Energizing field coils **32** simultaneously electromagnetically couples propeller shaft **22** to engine shaft **20** via eddy-current coupling between field exciter **30** and electric circuit **48** on rotating drum **46**. The strength of this electromagnetic coupling between propeller shaft **22** and engine shaft **20** depends on coupler energizing current I_{eA}. To make up for the engine load lost by mechanically decoupling propeller shaft **22** from engine shaft **20**, electromagnetic brake **26** supplies an artificial load on engine shaft **20** proportional to brake energizing current I_{eB}.

As illustrated in FIG. **2**, double-channel exciter **28** includes first and second channels **28*a*** and **28*b***. First channel **28*a*** includes first rotating rectifier **50*a***, first excitation windings **52*a***, and first rotating armature **54*a***. Second channel **28*b*** similarly includes second rotating rectifier **50*b***, second excitation windings **52*b***, and second rotating armature **54*b***. First channel **28*a*** feeds ELM clutch and eddy-current coupler **24**, while second channel **28*b*** feeds EM brake **26**. Each channel is energized by a different control current: first channel **28*a*** by first control current I_{cA}, and second channel **28*b*** by second control current I_{cB}. Coupler energizing current I_{eA} and brake energizing current I_{eB} depend on first control current I_{cA} and second control current I_{cB}, which are produced by first DC controller **64** and second DC controller **66**, respectively. Coupler energizing current I_{eA} and brake energizing current I_{eB} are controlled by modulating first control current I_{cA} and second control current I_{cB} based on rotor speeds.

Tachogenerator **60** produces propeller feedback voltage V_{fbP} based on the speed of propeller shaft **22**, and tachogenerator **62** produces engine feedback voltage V_{fbE} based on the speed of engine shaft **20**. Propeller feedback voltage V_{fbP} is compared with (e.g. subtracted from) propeller speed reference value sr_P to set or produce first control current I_{cA}, while engine feedback voltage V_{fbE} is compared with (e.g. subtracted from) engine speed reference value sr_E to set or produce second control current I_{cB}. Propeller and engine feedback signals V_{fbP} and V_{fbE} represent target or limiting rotational speeds of propeller shaft **22** and engine shaft **20**, respectively. Feedback signals and reference values may be compared digitally or as analog signals (e.g. by analog voltage summing). By conditioning coupler energizing current I_{eA} on propeller feedback voltage V_{fbP}, double-channel synchronous exciter **28** regulates propeller rotor speed ν_p so that propeller speed ν_p remains within acceptable bounds. Similarly, conditioning brake energizing current I_{eB} on engine feedback voltage V_{fbE} allows double-channel synchronous exciter **28** to regulate engine rotor speed ν_e to avoid engine overspeed conditions.

FIG. **3** is a close-up simplified cross-sectional view of integrated ELM clutch and eddy-current coupler **24**, illustrating field exciter **30**, field coils **32**, pole cores **34**, pole shoes **36**, friction clutch cone **38**, friction clutch cup **40**, spring **42**, clutch pad **44**, rotating drum **46**, electric circuit **48**, and gap spacer **68**. FIG. **3** further shows field lines indicating magnetic field densities within components of integrated ELM clutch and eddy-current coupler **24**. As described above with respect to FIGS. **1** and **2**, energizing field coils **32** of field exciter **30** produces a magnetic attraction between pole shoes **36** and friction clutch cup **38** that draws friction clutch cup **38** away from friction cup cone **40** in opposition to spring **42**. When clutch pad **44** is separated from friction clutch cup **40**, engine shaft **20** and propeller shaft **22** become mechanically decoupled. Energizing field coils **32** simultaneously produces changing magnetic fields through electric circuit **48** and rotating drum **46**, as shown via field lines in FIG. **3**. These changing magnetic fields induce eddy currents that produce a torque coupling between couple field exciter **30** and rotating drum **46** (and accordingly propeller shaft **22**). The strength of this eddy current coupling depends on coupler energizing current I_{eA}, as noted previously.

Pole shoes **36** and friction clutch cone **38** are separated by a gap g that varies as a function of coupler energizing current I_{eA}. In general, larger values of coupler energizing current I_{eA} will draw friction clutch cone **38** further towards pole shoes **36**, reducing the width of gap g. Gap g must be sufficiently wide (e.g. ~0.2 mm or more) to prevent friction clutch cone **38** from locking to pole shoes **36**. If gap g falls below this margin, residual magnetization may prevent spring **42** from separating pole shoes **36** from friction clutch cone **38**, even after coupler energizing current I_{eA} returns to zero. To preserve gap g between pole shoes **36** and friction clutch cone **38**, gap spacer **68** is disposed within gap g. Gap spacer **68** is a non-ferromagnetic spacing element that may, for instance, be secured to either pole shoes **36** or friction clutch cup **38**. Gap spacer **68** may, for example, be formed of plastic, aluminum, or brass.

EM device **16** configurably transfers torque from engine shaft **20** to propeller shaft **22**, allowing propeller speeds to be maintained and/or controlled during transient unloading conditions, e.g. during landing maneuvers. EM device **16** artificially loads engine shaft **20** to prevent damage from engine overspeeds, while allowing engine **12** to be operated at full power (i.e. without spooling down engine **12**) during transient unloading conditions. These improvements allow for safer and more reliable operation of turboprop vehicles.

The following are non-exclusive descriptions of possible embodiments of the present invention.

An electromagnetic device for overspeed control of a propeller driven by an engine shaft, the electromechanical device comprising: a clutch disposed to mechanically decouple the propeller from the engine shaft; an eddy-current coupler disposed to electromagnetically couple the propeller to the engine shaft when the clutch mechanically decouples the propeller from the engine shaft; and an electromagnetic brake disposed to artificially load the engine shaft when propeller load on the engine shaft is reduced by mechanically decoupling the propeller from the engine shaft.

The electromagnetic device of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations, and/or additional components:

wherein the clutch is an electromechanical clutch.

wherein the electromechanical clutch and the eddy-current coupling are integrated in a rotating electromagnetic assembly comprising: a field coil configured to receive a first energizing current; a pole shoe energized by the first energizing current to electromagnetically decouple a ferromagnetic friction clutch cone attached to the engine shaft from a friction clutch cup attached to the propeller; and a rotating drum attached to the friction clutch cup and coupled via eddy currents to the pole shoe with a coupling strength determined by strength of the first energizing current.

wherein the energizing current is set based on speed of the propeller compared to a speed reference.

wherein the electromagnetic brake is driven by a second energizing current, such that the artificial load is determined by strength of the second energizing current.

wherein the second energizing current is set based on speed of the engine shaft.

and further comprising a double-channel synchronous exciter with a first channel providing the first energizing current, and a second channel providing the second energizing current.

A method of controlling speed of a propeller on an engine shaft, the method comprising: mechanically decoupling the propeller from the engine shaft with an electromagnetic clutch in response to a potential overspeed event; electromagnetically coupling the propeller to the engine shaft with an eddy current coupler when the propeller is mechanically decoupled from the engine shaft; and artificially loading the engine shaft with an electromagnetic brake when the propeller is mechanically decoupled from the engine shaft.

The method of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations, and/or additional components:

wherein mechanically decoupling the propeller from the engine shaft comprises energizing a pole shoe attached to the engine shaft with a first energizing current to separate a friction clutch cone attached to the engine shaft from a friction clutch cup attached to the propeller.

wherein electromagnetically coupling the propeller to the engine shaft comprises inducing eddy currents in a rotating drum attached to the friction clutch cup via the energized pole shoe.

wherein slip of the electromagnetic coupling is determined by the first energizing current, and is greater than slip of the mechanical coupling.

wherein strength of the artificial loading is determined by a second energizing current.

wherein the first energizing current is set based on speed of the propeller compared with a first speed reference, and the second energizing current is set based on speed of the engine shaft.

wherein the first energizing current is provided by a first channel of a double-channel synchronous exciter, and the second energizing current is provided by a second channel of the double-channel synchronous exciter.

A propeller system comprising: a propeller on a propeller shaft; an engine disposed to drive the propeller shaft via an engine shaft; a clutch disposed to mechanically decouple the propeller shaft from the engine shaft; an eddy-current coupler disposed to electromagnetically couple the propeller shaft to the engine shaft when the clutch mechanically decouples the propeller from the engine shaft; and an electromagnetic brake disposed to artificially load the engine shaft when propeller load on the engine shaft is reduced by mechanically decoupling the propeller from the engine shaft.

The propeller system of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations, and/or additional components:

wherein the propeller is a propulsion propeller of a turboprop vehicle.

wherein the propeller has pitchable blades.

wherein the clutch and the eddy-current coupling are integrated in a rotating electromagnetic assembly comprising: a field coil configured to receive a first energizing current; a pole shoe energized by the first energizing current to electromagnetically decouple a ferromagnetic friction clutch cone attached to the engine shaft from a friction clutch cup attached to the propeller; and a rotating drum attached to the friction clutch cup and coupled via eddy currents to the pole shoe with a coupling strength determined by strength of the first energizing current.

wherein the energizing current is set based on speed of the propeller compared to a speed reference.

wherein the electromagnetic brake is driven by a second energizing current set based on the speed of the engine shaft, such that the artificial load is determined by strength of the second energizing current.

While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

The invention claimed is:

1. An electromagnetic device for overspeed control of a propeller driven by an engine shaft, the electromagnetic device comprising:

an electromechanical clutch disposed to mechanically decouple the propeller from the engine shaft;

an eddy-current coupler disposed to electromagnetically couple the propeller to the engine shaft when the clutch mechanically decouples the propeller from the engine shaft; and

an electromagnetic brake disposed to impose an artificial load on the engine shaft when a propeller load on the engine shaft is reduced by mechanically decoupling the propeller from the engine shaft;

wherein the electromechanical clutch and the eddy-current coupler are integrated in a rotating electromagnetic assembly comprising:

a field coil configured to receive a first energizing current;

a pole shoe energized by the first energizing current to electromagnetically decouple a ferromagnetic friction clutch cone attached to the engine shaft from a friction clutch cup attached to the propeller; and

a rotating drum attached to the friction clutch cup and coupled via eddy currents to the pole shoe with a coupling strength determined by a magnitude of the first energizing current.

2. The electromagnetic device of claim **1**, wherein the first energizing current is set based on a speed of the propeller compared to a speed reference.

3. The electromagnetic device of claim **1**, wherein the electromagnetic brake is driven by a second energizing current, such that the artificial load is determined by a magnitude of the second energizing current.

4. The electromagnetic device of claim **3**, wherein the second energizing current is set based on a speed of the engine shaft.

5. The electromagnetic device of claim **3**, further comprising a double-channel synchronous exciter with a first channel providing the first energizing current, and a second channel providing the second energizing current.

6. A method of controlling speed of a propeller on an engine shaft, the method comprising:

disengaging a mechanical coupling between the propeller and the engine shaft with an electromagnetic clutch in response to a potential overspeed event, by energizing a pole shoe attached to the engine shaft with a first energizing current to separate a friction clutch cone attached to the engine shaft from a friction clutch cup attached to the propeller;

engaging an electromagnetic coupling between the propeller and the engine shaft with an eddy current coupler when the propeller is mechanically decoupled from the engine shaft; and

imposing an artificial load on the engine shaft with an electromagnetic brake when the propeller is mechanically decoupled from the engine shaft.

7. The method of claim **6**, wherein engaging an electromagnetic coupling between the propeller and the engine shaft comprises inducing eddy currents in a rotating drum attached to the friction clutch cup via the energized pole shoe.

8. The method of claim **6**, wherein slip of the electromagnetic coupling is determined by the first energizing current, and is greater than slip of the mechanical coupling.

9. The method of claim **8**, wherein strength of the artificial load is determined by a second energizing current.

10. The method of claim **9**, wherein the first energizing current is set based on a speed of the propeller compared with a first speed reference, and the second energizing current is set based on speed of the engine shaft.

11. The method of claim 9, wherein the first energizing current is provided by a first channel of a double-channel synchronous exciter, and the second energizing current is provided by a second channel of the double-channel synchronous exciter.

12. A propeller system comprising:
- a propeller on a propeller shaft;
- an engine disposed to drive the propeller shaft via an engine shaft;
- a clutch disposed to mechanically decouple the propeller shaft from the engine shaft;
- an eddy-current coupler disposed to electromagnetically couple the propeller shaft to the engine shaft when the clutch mechanically decouples the propeller from the engine shaft; and
- an electromagnetic brake disposed to impose an artificial load on the engine shaft when propeller load on the engine shaft is reduced by mechanically decoupling the propeller from the engine shaft;
- wherein the clutch and the eddy-current coupler are integrated in a rotating electromagnetic assembly comprising:
  - a field coil configured to receive a first energizing current;
  - a pole shoe energized by the first energizing current to electromagnetically decouple a ferromagnetic friction clutch cone attached to the engine shaft from a friction clutch cup attached to the propeller; and
  - a rotating drum attached to the friction clutch cup and coupled via eddy currents to the pole shoe with a coupling strength determined by a magnitude of the first energizing current.

13. The propeller system of claim 12, wherein the propeller is a propulsion propeller of a turboprop vehicle.

14. The propeller system of claim 12, wherein the propeller has pitchable blades.

15. The propeller system of claim 12, wherein the energizing current is set based on a speed of the propeller compared to a speed reference.

16. The propeller system of claim 12, wherein the electromagnetic brake is driven by a second energizing current set based on a speed of the engine shaft, such that the artificial load is determined by a strength of the second energizing current.

17. The propeller system of claim 12, wherein a gap spacer is disposed between the pole shoe and the clutch to preserve a gap between the pole shoe and the friction clutch cup when the pole shoe is energized.

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